

10/579903
AP20 Rec'd PCT/PTO 19 MAY 2006

VERIFICATION OF A TRANSLATION

I, the below named translator, hereby declare that:
My name and post office address are as stated
below;
That I am knowledgeable in the English language and in the
language in which the below identified international
application was filed, and that I believe the English
translation of the international application No.
PCT/JP2004/018101 is a true and complete translation of the
above identified international application as filed.

I hereby declare that all statements made herein
of my own knowledge are true and that all statements made on
information and belief are believed to be true;
and further that these statements were made with the
knowledge that willful false statements and the like so made
are punishable by fine or imprisonment, or both, under Section
1001 of Title 18 of the United States Code and that such willful
false statements may jeopardize the validity of the application
or any patent issued thereon.

Date March 7, 2006

Full name of the translator Kazuo TAKEUCHI

Signature of the translator Kazuo TAKEUCHI

Post Office Address 3-3-5-207, Kamiyuzuki, Hachioji-shi,
Tokyo 192-0373 JAPAN

DESCRIPTION AP20 Rec'd PCT/PTO 19 MAY 2006

EXTERNAL CAVITY TYPE SEMICONDUCTOR LASER

Technical Field

5 The present invention relates to an external cavity type semiconductor laser that has a blue laser diode.

Background Art

10 In recent years, since semiconductor lasers are small and have low power consumption, they have been used for many information devices. Among them, 15 there is an external cavity type semiconductor laser that emits a beam whose wavelength is stabilized by an external beam having a predetermined wavelength.

20 Next, with reference to Fig. 1, a typical Littrow type semiconductor laser will be described. A multiple longitudinal mode laser beam emitted from a semiconductor laser device such as a laser diode 100 is 25 collimated by a lens (collimate lens) 101. The collimated beam reaches a grating 102. The grating 102 outputs a beam having a predetermined wavelength as a first order diffracted beam 103 corresponding to an arrangement angle of the grating 102. The first order diffracted beam 103 is reversely injected into the laser diode 100 through the lens 101. As a result, the laser diode 100 resonates with the injected first order diffracted beam and emits a single mode beam. The wavelength of the beam emitted from the laser diode 100

is the same as the wavelength of the first order diffracted beam 103 outputted from the grating 102. The rest of the laser beam that has reached the grating 102 is a 0-th order beam 104. The 0-th order beam 104
5 is reflected at the same angle as the incident angle.

Next, with reference to Fig. 2 and Fig. 3, a structure of a laser system that has a typical external cavity type semiconductor laser that is commercially available will be described. Fig. 2 is a plan view showing a laser system 120. Fig. 3 is a front view showing the laser system 120 seen toward a direction denoted by C in Fig. 2. The structure of the laser system 120 is the same as that of a laser system described in a periodical, L. Ricci, et al. "A compact
10 grating - stabilized diode laser system for atomic
15 physics", Optics Communications, 117 1995, pp 541 - 549.

The laser system 120 shown in Fig. 2 and Fig. 3 is composed of a laser section 130 that has a laser diode 121, a lens (collimate lens) 122, a grating 123, a first supporting portion 124, a first screw 125, a first groove 126, a second supporting portion 127, a second screw 128, and a second groove 129; a Peltier device 141; and a temperature control section 143 that
20 has a heat sink 142.

25 As are clear from Fig. 2 and Fig. 3, optical parts such as the lens 122 and the grating 123 are horizontally arranged on a mounting surface of the

laser system 120. An optical path of a laser beam is
nearly in parallel with the mounting surface. The
temperature control section 143 is disposed below the
laser section 130. The temperature control section 143
5 controls temperatures of structural components of the
laser section 130 such as the laser diode 121 and the
lens 122. The temperature control section 143 keeps
the temperature of the laser diode 121 constant. As a
result, a light source, which is the laser diode 121,
10 is stabilized.

As shown in Fig. 1, when the arrangement
angle of the grating 123 of the laser system 120 is
changed, a wavelength of the first order diffracted
beam that travels from the grating 123 to the laser
15 diode 121 varies. As a result, a wavelength of an
oscillated beam of the laser diode 121 is adjusted. A
0-th order beam D reflected on the grating 123 is
emitted to the outside.

The grating 123 is held by the first
20 supporting portion 124. The first supporting portion
124 has the first groove 126. When the first screw 125
mounted in the first supporting portion 124 is rotated,
a gap of the first groove 126 is partly widened or
narrowed. As a result, a horizontal arrangement angle
25 of the grating 123 slightly varies.

The similar mechanism that adjusts a vertical
angle of the grating 123 is disposed. The first

supporting portion 124 that supports the grating 123 is supported by the second supporting portion 127. The second supporting portion 127 has the second groove 129. Likewise, when the second screw 128 mounted in the 5 second supporting portion 127 is rotated, a gap of the second groove 129 is partly widened or narrowed. As a result, a vertical arrangement angle of the first supporting portion 124 and the grating 123 slightly varies.

10 Blue laser diodes as laser diodes 121 have been developed by several makers. These makers have begun using these laser diodes for optical discs and so forth. In addition, as described above, an external cavity type laser system has been used for a holography 15 memory writer that needs a single mode laser beam.

The maximum output of a commercially available laser system of the same type is up to 15 mW as a catalog value.

20 However, when the external cavity type semiconductor laser is used for a holography memory writer and so forth, a laser output of 30 mW or higher is needed. Conventional external cavity type semiconductor lasers have not yet accomplished such an output level.

25 The external cavity type semiconductor lasers accomplish a single mode with an external cavity. However, they may not accomplish a sufficient single

mode characteristic due to various factors.

Therefore, an object of the present invention is to provide an external cavity type semiconductor laser that has two features of a larger output and a more excellent single mode characteristic than conventional external cavity type semiconductor lasers or an external cavity type semiconductor laser having one of these features.

Another object of the present invention is to provide an external cavity type semiconductor laser that has a laser beam output of 30 mW or higher and that is capable of being used for a holography memory writer and so forth.

Disclosure of the Invention

The present invention is an external cavity type semiconductor laser, comprising: a semiconductor laser device having a plurality of layers including an activation layer; a window glass disposed opposite to a beam emission surface of the semiconductor laser device; a grating that receives a beam emitted from the semiconductor laser device through the window glass and returns a beam having a predetermined wavelength to the semiconductor laser device; and a lens disposed between the semiconductor laser device and the grating and collects the beam emitted from the semiconductor laser device, wherein the window glass is arranged in a first state or a second state, in the first state the window

glass is in parallel with a first axis nearly
perpendicular to a surface that is in parallel with at
least one of boundary surfaces of the activation layer
and other layers of the semiconductor laser device, the
5 window glass being nearly in parallel with at least one
of the boundary surfaces of the activation layer and
the other layers of the semiconductor laser device, the
window glass being nearly in parallel with the beam
emission surface of the semiconductor laser device, the
10 window glass being not in parallel with a second axis
perpendicular to the first axis, in the second state
the window glass is not in parallel with the first axis,
the window glass being nearly in parallel with the
second axis.

15 The present invention is an external cavity
type semiconductor laser, comprising: a laser diode
having a plurality of layers including an activation
layer; a window glass disposed opposite to a beam
emission surface of the laser diode; a grating that
receives a beam emitted from the laser diode through
20 the window glass and returns a beam having a
predetermined wavelength to the laser diode; and a lens
disposed between the laser diode and the grating and
collects the beam emitted from the laser diode, wherein
25 the window glass is arranged in a first state or a
second state, in the first state the window glass is in
parallel with a first axis nearly perpendicular to a

surface that is in parallel with at least one of
boundary surfaces of the activation layer and other
layers of the laser diode, the window glass being
nearly in parallel with at least one of the boundary
5 surfaces of the activation layer and the other layers
of the laser diode, the window glass being nearly in
parallel with the beam emission surface of the laser
diode, the window glass being not in parallel with a
second axis perpendicular to the first axis, in the
10 second state the window glass is not in parallel with
the first axis, the window glass being nearly in
parallel with the second axis, wherein the laser diode
and the grating are arranged so that the laser diode
supplies an S wave to the grating, wherein the laser
15 diode has an output power of at least 45 mW, wherein
when the laser diode emits a beam with an output power
of 45 mW or less, a kink does not occur, wherein a
reflectance of a beam emission surface of the laser
diode is 3 % or less, wherein a numerical aperture of
20 the lens is in the range from 0.3 to 0.7, wherein an
external cavity length is in the range from 10 mm to 30
mm, and wherein a reflectance of a first order
diffracted beam of the grating is in the range from
25 10 % to 30 %.

Brief Description of Drawings

Fig. 1 is a schematic diagram describing a
theory of operation of an external cavity type

semiconductor laser.

Fig. 2 is a schematic diagram showing a structure of a conventional laser system.

5 Fig. 3 is a schematic diagram showing a structure on one side of the laser system shown in Fig. 2.

Fig. 4 is a schematic diagram showing a conventional laser diode and associated parts.

10 Fig. 5 is a schematic diagram showing the laser diode and the associated parts seen from a different angle than the angle shown in Fig. 4.

Fig. 6 is a graph showing a relationship between a wavelength and an output power in the case that a single mode is not accomplished.

15 Fig. 7 is a schematic diagram showing an example of the external cavity type semiconductor laser according to the present invention.

20 Fig. 8 is a schematic diagram showing another example of the external cavity type semiconductor laser according to the present invention.

Fig. 9 is a graph showing a relationship between a wavelength and an output power in the case that a single mode is accomplished according to the present invention.

25 Fig. 10 is a graph showing an example of occurrence of a kink.

Fig. 11 is a schematic diagram showing an

example of a structure of a laser diode that suppresses occurrence of a kink.

Best Modes for Carrying out the Invention

The present invention is a modified external cavity type semiconductor laser that has a semiconductor laser device so as to increase a laser output and improve a single mode characteristic. In this example, the external cavity type semiconductor laser is an apparatus that has for example a semiconductor laser using a semiconductor laser device such as a laser diode, a lens, and a grating disposed at positions shown in Fig. 1. The laser diode is for example a blue laser diode that emits a beam having a wavelength ranging from for example 395 nm to 415 nm.

Next, modifications in the present invention will be successively described.

[1. Optimization of inclined angle of window glass - Suppression of multiple reflection]

As a first modification, a window glass of the semiconductor laser is inclined in a predetermined direction for a predetermine angle. Fig. 4 shows a conventional laser diode (semiconductor laser device) 1 and associated structural parts thereof. The laser diode 1 is composed of an activation layer 2 that contains a laser beam emission portion, and two layers 3 and 4 disposed above and below the activation layer 2. The layer 3 is composed of for example a P type clad

layer, a contact layer, and so forth. The layer 4 is composed of for example an N type clad layer, a guide layer, and so forth. To accomplish a low aspect ratio of the semiconductor laser device, an electron barrier layer and an intermediate layer may be disposed between the P type clad layer and the activation layer 2.

5 A heat sink 5 is disposed below the laser diode 1. The heat sink 5 diffuses heat generated from the laser diode 1 that operates by thermal conduction. 10 The heat sink 5 needs to be made of a material that has high heat conduction, high electric insulation, and high thermal expansion.

15 A laser beam 7 is emitted from a beam emission surface 8 of the activation layer 2 to the outside through a window glass 6. An external cavity type semiconductor laser that has a red laser diode or the like does not need the window glass 6. However, when an external cavity type semiconductor laser that has a blue laser diode does not use the window glass 6, 20 the laser diode may deteriorate. To prevent that, the window glass 6 shields the laser diode 1 from atmospheric air.

25 Fig. 5 shows the laser diode 1, the heat sink 5, the window glass 6, and so forth seen from an angle different than the angle shown in Fig. 4. Fig. 4 is a plan view of the these parts, whereas Fig. 5 is a front view thereof. In other words, a structure of the laser

diode 121 of the laser system 120 shown in Fig. 2 is shown in Fig. 4, whereas a structure of the laser diode 121 of the laser system 120 shown in Fig. 3 is shown in Fig. 5. The laser beam 7 is emitted from the laser diode 1 to the outside through the window glass 6.

5

When the shape of the beam emission surface 8 of the activation layer 2 shown in Fig. 4 is rectangular, since a spread angle of shorter sides becomes large, a sectional shape of the laser beam 7 is normally elliptical.

10

Conventionally, as shown in Fig. 4 and Fig. 5, since the window glass 6 and the beam emission surface 8 (laser edge surface) of the activation layer 2 are arranged in parallel, the laser beam is reflected by the window glass. Since the laser beam is multiply reflected, the single mode characteristic deteriorates.

15

Fig. 6 shows a relationship between a wavelength and an output power of the laser diode 1 in the case that the single mode characteristic deteriorates. A horizontal axis and a vertical axis of Fig. 6 represent a wavelength (nm) and an output power (μ W), respectively. A value on the vertical axis represents a power of a beam that an optical fiber as an input portion of a measurement instrument receives. This value is around one of several thousands of a value of a power of a beam that the laser actually emits.

20

25

As shown in Fig. 6, the output power peaks at

a wavelength of around 408.00 nm. This portion shows that the beam has a good single mode characteristic. However, there are several laser beams having an output power of 0.1 μ W (max) at wavelengths from 408.00 nm to 5 408.50 nm. As a result, it is clear that a single mode is not accomplished.

Thus, according to the present invention, to suppress multiple reflection due to the window glass, it is inclined in a predetermined direction for a 10 predetermined angle. Fig. 7 shows a first example of a external cavity type semiconductor laser modified in the foregoing manner. In the first example, a laser beam that is emitted from a laser diode 11 and that passes through a window glass 16 reaches in the same 15 direction as that shown in Fig. 4 (namely as shown in Fig. 7A) a grating 123 inclined as shown in Fig. 2.

The laser diode 11 is composed of an activation layer 12 containing a laser beam emission portion and layers 13 and 14 disposed above and below 20 the activation layer 12. The layer 13 is composed of for example a P type clad layer, a contact layer, and so forth. The layer 14 is composed of for example an N type clad layer, a guide layer, and so forth. To accomplish a low aspect ratio of the semiconductor 25 laser device, an electron barrier layer and an intermediate layer may be disposed between the P type clad layer and the activation layer 12.

A heat sink 15 is disposed below the laser diode 11. The heat sink 15 diffuses heat generated from the laser diode 11 that operates by thermal conduction. The heat sink 15 needs to be made of a material that has high heat conduction, high electric insulation, and high thermal expansion.

A laser beam 17 is emitted from a beam emission surface 19 of the activation layer 12 to the outside through a window glass 16. An external cavity type semiconductor laser that has a red laser diode or the like does not need the window glass 16. However, when an external cavity type semiconductor laser that has a blue laser diode does not use the window glass 16, the laser diode may deteriorate. To prevent that, the laser diode 11 is airtightly contained in a cylindrical can 21 so that the window glass 16 shields the laser diode 11 from atmospheric air.

Fig. 7B is a schematic diagram showing a first example of the present invention. A first axis 18A shown in Fig. 7B is nearly perpendicular to a surface that is in parallel with at least one of boundary surfaces of the activation layer 12 and the other layers of the laser diode 11. A second axis 18B is nearly in parallel with at least one of the boundary surfaces of the activation layer 12 and the other layers of the laser diode 11. The second axis 18B is nearly in parallel with the beam emission surface 19 of

the laser diode 11. In addition, the second axis 18B is perpendicular to the first axis 18A.

In this example, the surface of the window glass 16 is inclined to the beam emission surface 19 of the laser diode 11 so that the surface of the window glass 16 is in parallel with the second axis 18B, but not in parallel with the first axis 18A. In this example, it is assumed that an angle of the first axis 18A and the window glass 16 is denoted by A. In this example, A is a small angle for example 1°.

When the surface of the window glass 16 is inclined to the first axis 18A for e.g. 1.6°, namely A = 1.6°, since wave front aberration is as large as $0.15\lambda P - V$ (peak to valley), which cannot be practically used. Thus, an allowable range of the inclination angle A of the surface of the window glass 16 is very narrow. In the example shown in Fig. 7B, although the window glass 16 is inclined so that an upper portion of the window glass 16 is close to the laser diode 11. Instead, a lower portion of the window glass 16 may be close to the laser diode 11.

Next, the wave front aberration will be described. A beam emitted from a point light source propagates as an equi-phase spherical wave. However, when the optical system has an aberration, the equi-phase wave surface is not a spherical wave in an image space. The deviation from the spherical wave is

generally referred to as the spherical aberration. "P - V" means a difference between a top and a bottom of a distortion of a wave front. "0.15 $\lambda P - V$ " means that the difference is one wavelength λ (for example, 410 nm) times 0.15.

5

Fig. 8 shows a second example of which a window glass is inclined in a predetermined direction for a predetermined angle. As shown in Fig. 8A, in the second example, a laser beam is emitted from a laser diode 11 through a window glass 16 to an inclined grating 123 as shown in Fig. 3. In addition, the laser diode 11 shown in Fig. 8 has a plurality of layers corresponding to the activation layer 11 and the layers 13 and 14 like the laser diode 11 shown in Fig. 7.

10

Fig. 8B is a schematic diagram showing the second example of the present invention. A first axis 18A shown in Fig. 8B is nearly perpendicular to a surface that is in parallel with at least one of boundary surfaces of the activation layer and other layers of the laser diode 11. A second axis 18B is nearly in parallel with at least one of the boundary surfaces of the activation layer and the other layers of the laser diode 11. The second axis 18B is nearly in parallel with a beam emission surface 19 of the laser diode 11. In addition, the second axis 18B is perpendicular to the first axis 18A.

20

25

In the second example, the surface of the

window glass 16 is inclined so that the surface of the window glass 16 is in parallel with the first axis 18A, but not in parallel with the second axis 18B. In this example, it is assumed that an angle of the second axis 18B and the surface of the window glass 16 is denoted by B.

5 When B is for example 5° or larger, since multiple reflection decreases, an excellent single mode characteristic can be obtained. However, when the 10 window glass 16 is excessively inclined, aberration of the window glass 16 becomes large. As a result, an aberration characteristic of the laser deteriorates.

15 In a region of $1/e^2$, namely a region of which optical intensity drops to $1/e^2$, to satisfy a wave front aberration of $0.15\lambda P - V$ or less, an inclination angle of 12° or less is required. To satisfy a wave front aberration of $0.1\lambda P - V$ or less, an inclination angle of 8° or less is required. In the example shown 20 in Fig. 8, the window glass 16 is inclined so that an upper portion of the window glass 16 is close to the laser diode 11. Instead, the window glass 16 may be inclined so that a lower portion of the window glass 16 is close to the laser diode 11.

25 As described above, the blue laser diode needs to be shielded from atmospheric air to prevent the diode from deteriorating. Thus, the window glass is an essential structural part. This modification

allows an excellent single mode characteristic to be accomplished in the foregoing structure.

Fig. 9 is a graph showing a relationship between a wavelength and an output power in the case that the window glass is inclined for 6° in the structure shown in Fig. 8, namely $B = 6^\circ$. The graph shows that an excellent single mode characteristic is accomplished around a wavelength of 406.94.

[2. Optimization of incident wave to grating -
10 Improvement of reflectance of grating]

A laser beam emitted from a laser diode is reflected as a 0-th order beam by a grating. The 0-th order beam exits to the outside. The 0-th order beam is used for various applications such as a holography 15 memory writer. Thus, it is preferred that the power of the 0-th order beam be large. Since the 0-th order beam is reflected like a mirror, reflectance thereof largely depends on whether the 0-th order beam is an S wave or a P wave.

20 A P wave has a Brewster angle. When the P wave reaches the grating at an inclined angle thereto like the foregoing external cavity type semiconductor laser, the reflectance of the 0-th order beam is low. In contrast, when the S wave reaches the grating at an 25 inclined angle thereto, the reflectance of the 0-th order beam is high. Thus, when the S wave reaches the grating, a large power can be obtained. To allow the S

5 wave reach to the grating, arrangements of the semiconductor laser and the grating need to be adjusted with respect to a polarizing direction of the semiconductor laser and a reflecting direction of the grating.

[3. Optimization of structure of laser diode - Removal of kink]

10 A light source of a single mode laser beam that is finally obtained is the laser diode 1 shown in Fig. 4. Thus, the laser diode 1 needs to have an output power higher than a required laser power. In other words, the laser diode 1 alone needs to emit a laser beam having a laser power higher than the required laser power in a free run state.

15 An experiment shows that the power of a laser beam that exits to the outside is around 2/3 of the output power of the laser diode 1 because the laser beam passes through a window glass, a lens (collimate lens), and a grating. When a laser beam is used for a 20 holography memory writer as described above, a power of 30 mW or higher in a single mode is required. An output power required for a laser diode can be obtained by the following formula 1.

$$30 \text{ (mW)} \times 3/2 = 45 \text{ (mW)} \dots \text{(Formula 1)}$$

25 Most of the remaining 1/3 of the output power of the laser diode 1 returns to the laser diode 1 as a first order diffracted beam of the grating. Thus, this

beam does not exit to the outside.

As described above, to obtain a power of 30 mW or higher of a finally obtained single mode laser beam, the laser diode 1 needs to have an output power of 45 mW or higher. However, the output laser beam should be free of a kink in all the power. The kink is a boundary of modes. Before the kink occurs, a beam is emitted in a single lateral mode. After the kink occurs, multiple lateral modes occur. In the multiple lateral mode, it is difficult to accomplish a single mode with an external cavity. Thus, it is preferred that no kink occur in all the power of 45 mW required for the laser diode 1.

Fig. 10 is a graph showing a relationship between a current (mA) and an output power (mW) of the laser diode 1. In this example, a kink occurs at an output power of around 20 mW. As is clear from the graph, when a current supplied to the laser diode 1 is increased to some extent, the output power of the laser diode 1 is zero. When the current becomes around 30 mA, the output power begins to increase. Thereafter, the as the current increases, the output power proportionally increases. However, when the output power becomes around 20 mW (the current becomes around 50 mA), there is a point of which as the current increases, the output power does not increase. This means that while the laser diode 1 outputs a laser beam

having the same wavelength, a mode the laser beam that the laser diode 1 emits changes. This point is a kink.

As described above, the kink is undesirable for a single mode. Thus, it is necessary to remove the 5 kink or cause it to occur at an output power of 45 mW or higher.

To do that, a chip of a laser diode 30 is structured as shown in Fig. 11. This structure has been proposed in "100 mW kink-free, low aspect ratio, 10 blue-violet semiconductor laser," Takashi Mizuno, et. al, Proceedings of the 11th Sony Research Forum (2001).

In this structure, an n-GaN layer 33 having a low defect density region is made on a sapphire substrate 31 by ELO (Epitaxial Lateral Overgrowth). 15 Thereafter, an N clad layer 34, a guide layer 35, an activation layer 36, an intermediate layer 37, an electron barrier layer 38, a P clad layer 39, and a contact layer 41 are successively crystallized. In this example, the N clad layer 34 is an n-AlGaN clad 20 layer; the guide layer 35 is an n-GaN guide layer; the activation layer 36 is a GaInN multiple quantum well activation layer; the intermediate layer 37 is a GaInN intermediate layer; the electron barrier layer 38 is a p-AlGaN electron barrier layer; the P clad layer 39 is 25 a p-GaN/AlGaN ultra-lattice clad layer; the contact layer 41 is a p-GaN contact layer. A P electrode 43 is composed of for example Pd/Pt/Au. An N electrode 42 is

composed of Ti/Pt/Au.

In this structure, a ridge side surface buried layer 40 is formed. In the ridge side surface buried layer 40, side surfaces of the contact layer (ridge) 41 are buried with two layers of insulation films that are for example a SiO_2 layer and a Si layer. A single lateral mode laser beam hardly diffuses (spread) in the direction of the boundary of each layer of the laser diode 30, a multiple lateral mode laser beam diffuses in the direction. Thus, the ridge side surface buried layer 40 hardly absorbs a single lateral mode laser beam, but selectively absorbs a multiple lateral mode laser beam. As a result, a kink is suppressed. At worst, a kink occurs at a high power region.

In this example, it is preferred that a stripe width W corresponding to a width of the contact layer be $1.6 \mu\text{m}$ or less. When this width is narrow, a multiple lateral mode laser beam hardly occurs.

[4. Optimization of reflectance of beam emission edge surface of laser diode - Effective beam reception of first order diffracted beam]

Since the material of the beam emission portion of the laser diode 1 shown in Fig. 4 has a high refractive index, the beam emission surface 8 reflects a beam that reaches from the outside. However, when the front surface of the beam emission surface 8 is

coated, the reflectance can be decreased to almost 0 %. The beam emission surface 8 is a surface on which a first diffracted beam returned from the grating to the laser diode 1 is received. The higher the reflectance of the beam emission surface 8 becomes, the lower the received light amount of the first order diffracted beam becomes.

5 An experimental result shows that a beam emission surface having a reflectance ranging from 0 % to 10 % accomplishes a single mode laser beam. However, 10 when the beam emission surface has a high reflectance, it is difficult to accomplish a signal mode. In addition, a large part of a first order diffracted beam returned from the grating is wasted. In contrast, when 15 a beam reflection surface having a very low reflectance is required, the yield will decrease due to a coating process. Thus, with respect to these conditions, it is preferred that the reflectance of the beam emission surface of the laser diode 1 be 3 % or less.

20 [5. Optimization of numerical aperture of collimate lens - Effective beam reception of first order diffracted beam]

25 As shown in Fig. 2 and Fig. 3, a collimate lens is disposed between a laser diode and a grating. When a numerical aperture (NA) of the collimate lens is small, for example 0.19, a first order diffracted beam returned from the grating is not stopped by the

collimate lens. Thus, the first order diffracted beam is spread and received on the beam emission surface 8 of the laser diode. Thus, only a part of the first order diffracted beam is returned to the laser diode.

5 As a result, it becomes difficult to accomplish a single mode.

In contrast, when the numerical aperture of the collimate lens is for example 0.4 or 0.6, it is easy to accomplish a single mode. It can be expected

10 that a lens having a numerical aperture that is higher than 0.4 or 0.6 allows a single mode to be accomplished. However, it is difficult to produce a lens having a high numerical aperture. With respect to these

15 conditions, it is preferred that the numerical aperture of the collimate lens be in the range from around 0.3 to 0.7.

[6. Optimization of external cavity length]

A distance from a semiconductor laser device such as a laser diode to a grating of the external cavity type semiconductor laser shown in Fig. 2 and Fig. 20 3 is referred to as an external cavity length. Experimental results show that when the external cavity length is 10 mm, 15 mm, 20 mm, 25 mm, and 30 mm, stability is high. Thus, it is preferred that the

25 external cavity length be in the range from 10 mm to 30 mm. In this example, the external cavity length represents an optical distance in consideration of the

refractive index and so forth of the window glass and the lens.

In addition, theoretically, the shorter the external cavity length is, the lesser a mode hop of which the current mode changes to another mode occurs. Thus, with respect to these conditions, it is more preferred that the external cavity length be in the range from 10 mm to 20 mm.

[7. Optimization of reflectance of first order diffracted beam on grating]

Experimental results show that when gratings that have reflectances of 20 % and 40 % of a first order diffracted beam are used, nearly the same single mode characteristic is obtained. As described above, a first order diffracted beam is returned to the laser diode to emit a single mode laser beam. Thus, a predetermined light amount of a first order diffracted beam is required. However, when the light amount of the first order diffracted beam is excessive, it will damage the laser diode and decrease an emission beam (0-th order beam). Thus, a proper reflectance is in the range from 10 % to 30 %.

In the foregoing, an external cavity type semiconductor laser that has a blue laser diode was exemplified. Except for the third modification (optimization of structure of laser diode - removal of kink), all the modifications can be applied to external

cavity type semiconductor lasers having another type of a semiconductor laser device.

In addition, the foregoing modifications are to accomplish a larger output and/or a more excellent 5 single mode than a conventional external cavity type semiconductor laser. To accomplish an ideal external cavity type semiconductor laser, it is desired that all the modifications be combined. However, when one or a combination of two or more of the modifications is used, 10 the foregoing object can be accomplished to some extent.

According to the present invention, an external cavity type semiconductor laser having two features of a larger output and a more excellent single mode characteristic than a conventional external cavity 15 type semiconductor laser or an external cavity type semiconductor laser having one of these two features is provided. In addition, according to the present invention, an external cavity type semiconductor laser having a laser beam output of 30 mW or more and that 20 can be used for a holography memory writer or the like is provided.